Machinery Messages

Rider band wear measurement in reciprocating compressors

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For many years, Bently Nevada has provided systems for the reciprocating machinery industry. Our ability to provide innovative solutions has increased as the number of requests for reciprocating machinery information systems has grown. One key parameter that has been vital to the business of many of our customers is rod drop monitoring to assess rider band condition.

Measurement description

Rod drop monitoring is used on horizontal reciprocating compressors. This type of machine, whether lubricated or nonlubricated, typically uses TFE or plastic rider bands (also called rider rings) to support the piston in the cylinder. The rider bands are expendable parts which may require frequent replacement. Machines are stopped at regular intervals, typically every few months, to check for rider band wear. To accomplish this, the suction and discharge lines must be closed, the cylinder must be purged of hazardous gasses, the unit blocked, and a valve removed. A feeler gauge is then inserted through the valve hole to measure the clearance between the bottom of the piston and the cylinder bore.

A more efficient method of measuring rider band wear is to use a proximity probe, mounted vertically to the packing case, to measure the position of the piston rod. Probe gap voltage can then be read with the 3300/81 Six Channel Rod Drop Monitor. The monitor uses a Keyphasor® probe to provide a once-per-revolution crankshaft pulse. This pulse is used as a reference, so an instantaneous rod position can be displayed. There are three main advantages to this method of rod drop measurement.

First, by taking readings at only one point in the stroke, the effects of scratches, wear, or rod coatings are minimized. Second, the most effective point in the stroke can be selected for taking the reading. Typically, this will be just before, or just after, bottom dead center (BDC), when the dynamic forces on the piston and crosshead have a minimal effect on the reading.

Third, since we know where the center of the piston is at this instant, the monitor can correct for the geometry of the machine and display the amount of actual rider band wear.

The 3300/81 Monitor provides two levels of alarm, Alert and Danger, for each channel. This monitor eliminates the need to periodically stop the machine and inspect for rider band wear. In addition, the monitor provides the information to develop a wear trend as part of a predictive maintenance program, unlike other rod drop indicators which provide only an alarm on excessive rider band wear.

Application

Many reciprocating machines in chemical plants and refineries are candidates for rod drop monitoring. In particular, nonlubricated machines used in oil sensitive processes are excellent candidates for rod drop monitoring, since the rider band provides the only buffer against contact between the piston and the cylinder. In lubricated piston machines, which make up the majority of machines in chemical plants and refineries, water and other contaminants in the gas stream can either wash out or break down the lubrication. The result is rider band wear. Hydrogen machines in refineries are also excellent candidates for rod drop, since they are fairly critical and are susceptible to water and other contaminants, especially iron sulfides and acids.

On a lubricated piston machine that compresses clean sweet dry gas, such as a natural gas pipeline compressor, there is less need for rod drop monitoring, as the rider bands don't wear very much. However, the 3300/81 Monitor can protect against damage from loss of lubrication to the piston. If lubrication is lost, the monitor shows significant rod drop over a short period of time. It can help you save a natural gas machine from failing.

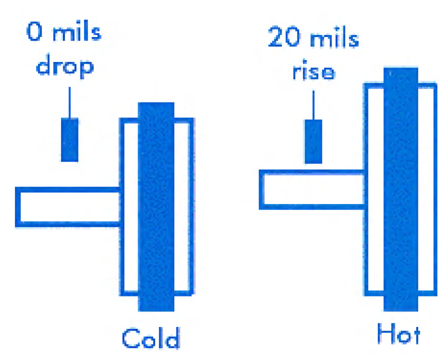

Figure 1
Piston thermal growth

Thermal and dynamic effects

There are two important things to consider when monitoring rod drop: Thermal and dynamic effects.

First, when a piston is heated by the compression process, thermal growth occurs and the radius of the piston becomes larger. Since the rod drop probe is measuring the position of the piston rod relative to a fixed point on the packing box, the piston thermal growth appears as rod rise if the monitor is zeroed when the machine is cold (Figure 1). When installing new rider bands, the monitor should always be rezeroed after at least 2 hours of run time, to set a hot zero. If this is not done, the monitor will not be as effective. The hot zero compensates for thermal growth effects that change the probe gap.

Changing process conditions, including gas molecular weight, suction pressure, or unloading the machine with pocket or valve unloaders, also affects the heat of compression. This could affect the thermal growth of the piston, resulting in a rod drop reading that varies somewhat with process conditions. Thermal growth effects are more substantial on machines which use aluminum pistons, since the coefficient of thermal expansion for aluminum is much higher than that of steel or cast iron. Thermal effects are also more noticeable on large diameter pistons.

Second, the rod drop measurement is also influenced by the dynamic effects of some machines. There are two main categories of dynamic effects, crosshead vertical motion and rod flex.

Crosshead vertical motion is due to the net force on the crosshead wrist pin as a result of applied torque, rod load, and cylinder alignment (Figure 2). On one side of a horizontal balanced opposed machine, the net vertical force is up during most of the stroke. As a result, the crosshead loads in the upper guide. This is referred to as the "up running crosshead." At the ends of the stroke, the vertical force is zero, so, for a portion of the stroke near top dead center (TDC) and bottom dead center (BDC), the crosshead moves from the upper guide to the lower guide. This movement affects the rod drop measurement.

Rod flex is due to the net horizontal force on the piston rod that causes the piston to compress the gas. The net horizontal force is the sum of the inertia forces of the reciprocating parts plus the net gas pressure on the piston. The pressure force is calculated over the stroke by measuring the pressure in the cylinder and multiplying it by the area of the piston face at both head end and crank end, according to this formula:

$$F(\Theta) = P_{HE}(A_P) - P_{CE}(A_P - A_R)$$

Where

P_{HE} = Head End Pressure
P_{CE} = Crank End Pressure
A_P = Piston Area
A_R = Rod Area
Θ = Crank angle

Over the stroke, in a double acting cylinder, the force reverses from acting toward the crankcase to acting away from the crankcase. The inertia force is simply the mass of the reciprocating parts multiplied by the acceleration of those parts: F = Ma. The acceleration changes in both magnitude and sign over the course of the stroke, even in a single acting cylinder. At bottom dead center (BDC), the acceleration is maximum as the piston moves out toward top dead center (TDC). At midstroke, the velocity is maximum and the acceleration is zero.

As the piston approaches top dead center, the sign of the acceleration has changed and the piston is decelerated to a stop at the end of the stroke. This acceleration curve is very much like the motion of a pendulum. Figure 3 is a graph which shows how the pressure and inertia forces, over the stroke, yield the net force at the crosshead wrist pin on a double-acting compressor. Due to the nature of this force, the piston rod is in compression over part of the stroke, and in tension over the remainder of the stroke. The largest force loading occurs just prior to the ends of the stroke. If the piston were perfectly aligned with the crosshead, the rod would flex very little. However, any misalignment causes the rod to flex, especially while the rod is in compression. The changing machine load has a very definite effect on rod load, and the vertical load on the crosshead. On some machines, the rod drop reading changes with load as pockets are opened or valves unloaded (single-acting cylinder machines). As a result, the rod drop reading may change somewhat as pockets are opened or valves uploaded.

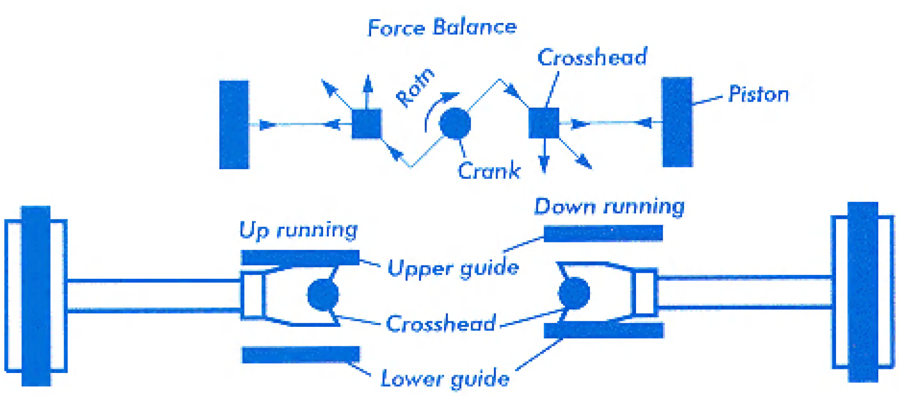

Figure 2
Vertical forces

Installation recommendations

The key for rod drop monitoring in machines with excessive thermal or dynamic motion effects is to pick the right trigger angle, to acknowledge that there will be some float in the reading, and to trend the reading. Choose a trigger angle corresponding to the moment when the crosshead is loaded in the guide, the piston rod flex is minimal, and the probe is close to the piston. The trigger point that satisfies these conditions, when the machine is under full load, however, may not satisfy all conditions when the machine is partially loaded. For instance, the crosshead may not be loaded when the machine is at the same trigger angle under partial

load. To select a trigger angle under these conditions, evaluate the waveform at each load step and pick a trigger angle that provides consistent results across all machine load ranges.

The reading can be trended in a Distributed Control System (DCS) or with a Bently Nevada Data Manager®. Over time, a trend reveals machine wear that may not be apparent in day-to-day measurements influenced by thermal or dynamic motion effects.

Proper setup and installation are the key elements to successful rider band wear monitoring. One of the main advantages of Bently Nevada's 3300/81 Monitor is that the drop measured at the probe can be corrected to indicate the amount of actual rider band wear (Figure 4). To accomplish this, simply enter the connecting rod length, piston to wrist pin length, stroke length and probe location into the 3300/81.

The probe must be properly supported and located. Thermal growth or vibration of the probe mounting can significantly impact the reading, especially if the probe does not remain perpendicular to the rod. In addition, the accuracy of the measurement increases the closer the probe is to the piston. Ideally, the probe should be mounted right inside the cylinder; the next best place is on the packing box. Mounting probes near the crosshead is less effective.

Rod material should be evaluated for each installation, so the correct probe calibration curve can be selected. Coatings or runout can significantly affect the probe curve, the waveform or the appropriate trigger point. In addition, a probe of proper range must be used, and it must be gapped at a point where the rod stays in range, even during the thermal growth of the piston. Barriers reduce the effective range of the probe. If the required range is near the range of the probe, barriers may cause a problem.

The trigger angle should be set at a point in the stroke where inertia forces and gas loads cause the piston to ride in the bottom of the cylinder and where the crosshead is loading its guide. Avoid the ends of the stroke; at these points, the inertia forces and vertical forces are transient. Research and the experience of our customers have led us to conclude that 240° past head end TDC is the best place to start. At this point, for most machines, the rod flex is minimal, the crosshead is loaded in a guide, and the piston is close to the probe. If this doesn't provide good results, it may be due to installation or dynamic issues, and the waveform should be evaluated for the best trigger point.

A checklist for installation and setup includes:

1) Probe solidly mounted close to the cylinder (usually on the packing box).
2) Correct parameters programmed into the monitor (connecting rod length, stroke length, etc.).
3) Calibration curve generated from the actual piston rod material and programmed into the monitor.
4) A probe of appropriate range.
5) Appropriate trigger angle selected.
6) Monitor rezeroed after about two hours of loaded run time (to correct for piston thermal growth).

Bently Nevada Product Service can help setup, calibrate and program the 3300/81 Monitor.

Conclusions

In refineries and chemical plants, reciprocating compressor availability has become a major business problem. The success of rotating machinery reliability programs has raised business managers' expectation levels. They are less tolerant of reciprocating machinery downtime. Industry competition has put pressure on plant managers to produce more with less. In the past, reciprocating compressors were normally spared. Now the spares are used to boost plant output, increasing the impact of maintenance outages.

Rider band wear measurement provides two primary benefits for users of reciprocating machinery. It provides protection against damage to the cylinder liner, due to worn rider bands, and it facilitates predictive maintenance by trending rider band wear. The 3300/81 Six Channel Rod Drop Monitor can help you keep your reciprocating machines online and producing.

Steven Schultheis is the Marketing Manager for Reciprocating Machinery. He can answer your questions regarding rod drop and other reciprocating machinery monitoring applications. Call him at Bently Nevada's Houston, Texas office (713) 640-1111, or contact your nearest Bently Nevada sales representative. ■

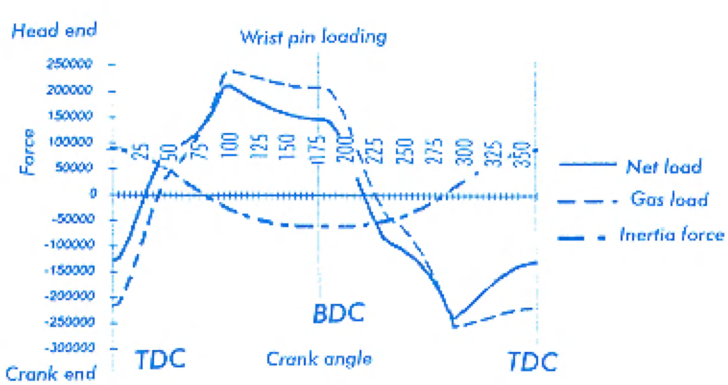

Figure 3
Force loading at wrist pin due to pressure and inertia

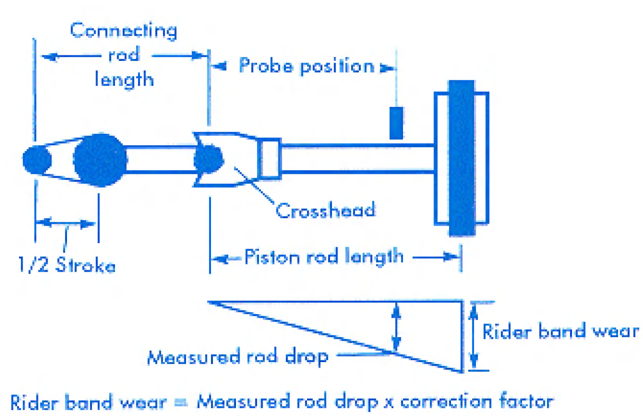

Figure 4
Machine parameters